Preventing visual field deficits from neurosurgery using intraoperative MRI

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Purpose: Anterior temporal lobe resection (ATLR) is an effective treatment for refractory temporal lobe epilepsy (TLE)[1] but may result in a visual field deficit (VFD) that precludes driving[2]. Diffusion tensor imaging tractography enables *in vivo* delineation of the optic radiation for surgical planning[3,4] but brain shift following craniotomy renders preoperative imaging inaccurate[5]. We assessed whether display of optic radiation tractography during ATLR can reduce the severity of VFD and whether correction for brain shift using intraoperative MRI (iMRI) is beneficial.

Methods: We studied 21 patients undergoing ATLR (age 23-63 years, median 36 years; 8 male). Preoperative tractography of optic radiation was performed as previously described using the Camino toolkit[6]. Patients underwent surgery in an iMRI suite at the National Hospital for Neurology and Neurosurgery equipped with a 1.5T Siemens Espree scanner, BrainLAB VectorVision sky navigation platform and an OPMI Pentero confocal surgical microscope for image injection (Figure 1). The optic radiation was displayed on the navigation and operating microscope displays either without (9 patients) or with (12 patients) correction for brain shift (Figure 2). BrainLAB software was used for image registration without brain shift correction. A custom-written pipeline incorporating corrections for gradient non-linearities and magnetic susceptibility artefacts using field maps[7] and Fast Free Deformation non-linear registration based on cubic B-splines and implemented on a graphical processing unit was used for brain shift correction[8].

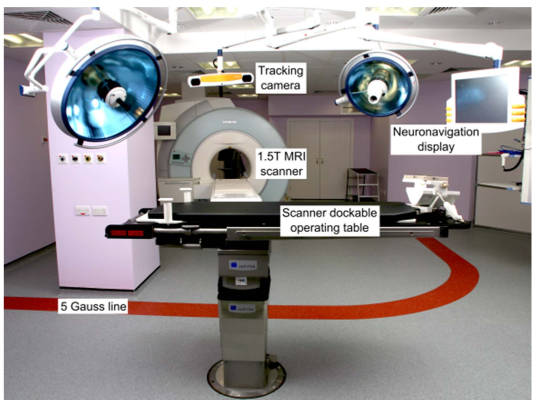

Figure 1. Intraoperative MRI setup at the National Hospital for Neurology and Neurosurgery, Queen Square, London. Surgery takes place outside the 5 Gauss line and the patient can be transferred to/from the 1·5T MRI scanner during surgery.

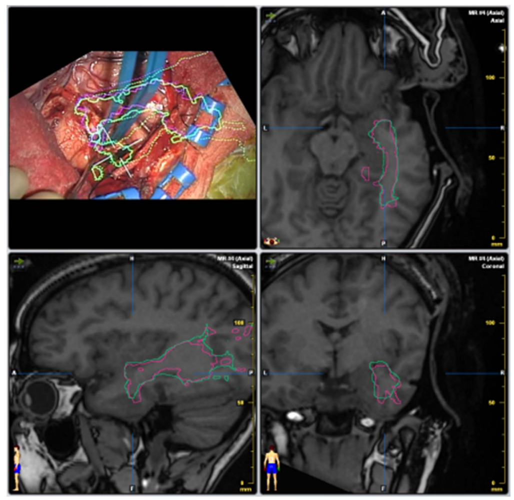

Figure 2. BrainLAB display following initial dissection in a patient undergoing right ATLR. The optic radiation before (pink) and after (green) correction for brain shift is superimposed with the solid outlines referring to the structure in the focal plane and the dashed outlines referring to the maximum extent below this. In the top left panel, the operating microscope view with these outlines and the ventricle (blue) is shown flipped and rotated to correspond with the sagittal view.

VFD were quantified using Goldmann perimetry and eligibility to drive was assessed by binocular Esterman perimetry 3 months after surgery. Secondary outcomes included seizure freedom and extent of hippocampal resection. The maximum degree of brain shift in the optic radiation and of a key landline, the anterior tip of the lateral ventricle was also quantified. The comparator was 44 patients who underwent ATLR without iMRI (age 17-68 years, median 39 years; 17 male).

Results: VFD in the contralateral superior quadrant were significantly less (p=0.043) with iMRI guidance (0-49.2%, median 14.5%) than without (0-90.9%, median 24.0%). No patient in the iMRI cohort developed a VFD that precluded driving whereas 13% of the non-iMRI cohort failed to meet UK driving criteria. In all but 2 patients, the surgeon reported using a more anterior approach than in the historical cohort consequent to the display of the optic radiation. Outcome did not differ between iMRI guidance with and without brain shift correction. Seizure outcome and degree of hippocampal resection were unchanged. Within the optic radiation, the maximum displacements were 2.8-6.8mm (mean 4.3mm) at timepoint 1 (after initial dissection) and 6.7-12.8mm (mean 9.3mm) at timepoint 2 (end of surgery to confirm adequate resection). The displacement of the anterior tip of the lateral ventricle was only 0.9-3.2mm (mean 1.9mm) at timepoint 1 (not visible at timepoint 2).

Discussion: Display of the optic radiation with image guidance reduces the severity of VFD and did not affect seizure outcome or hippocampal resection. Intraoperative correction for brain shift was possible within 8-9 minutes, the same time taken to transfer a patient from the scanner back to the operating table but did not further improve outcome. This is likely to be due the minimal displacement of the anterior tip of lateral ventricle, which is closely related to the anterior tip of Meyer's loop (maximum 3.2mm, mean 1.9mm) with negligible movement in the antero-posterior direction which is the most critical direction when attempting dissection anterior to the optic radiation.

Conclusion: This study implies that display of optic radiation tractography in the operating microscope led to a change in surgical approach to avoid the optic radiation and mitigate the risk of causing a VFD. As interventional MRI did not is expensive, prolongs surgery and is not widely available, our next step is to assess the benefit of incorporation of probabilistic tractography of the optic radiation into the operating microscope display of a commonly used neuronavigation system such as StealthStation, which would make this advance widely applicable.

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